BASIC MATHEMATICS FOR WATER AND SEWAGE OPERATION COURSE

Training & Certification
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Ministry
of the
Environment

Ontario

The Honourable
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PART A

ARITHMETIC REVIEW TEST

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PREFACE

An important function of the Water or Sewage Treatment Plant Operator is to keep his plant effectively tuned to operate at peak efficiency. Most tests of plant efficiency require an understanding of basic mathematics to enable the operator to interpret results.

As course time is too short either to adequately teach or to make a comprehensive review of basic mathematics, this booklet has been prepared to help the trainee in review before coming to the following courses:

- Basic Sewage Treatment Operation
- Basic Water Treatment Operation
- Activated Sludge Workshop
- Surface Water Treatment Workshop

This booklet consists of four parts:

Part A is a test which the individual should self administer before proceeding to the actual review. Answers are appended.

Part B is mathematics common to all courses.

Part C is mathematics for candidates of Water Treatment Plant Operation courses, and includes a review test.

Part D is mathematics for candidates of Sewage Treatment Plant Operation courses, and includes a review test.

Objectives

Trainee will be able to:

Perform basic mathematical calculations in addition, subtraction, multiplication, division, ratio and proportion, decimals, units.

In the case of WATER treatment:

Apply basic mathematical calculations to practical everyday use as required in a modern water treatment plant.

In the case of SEWAGE treatment:

Solve practical mathematical calculations in sewage plant operation, such as:

(a) determining chlorine demand;
(b) flow through the plant;
(c) determine the detention time;
(d) determine the volume of sludge.

Solve a sample problem using data from a typical activated sludge plant.

Part A - Arithmetic Review Test

1. ADD: (CHECK YOUR ANSWERS! See page 9)

195	205	9876
796	643	5348
____	____	____

$4/7 + 2/3 =$ ____________

$12.4 + 36.5 + 41.1 =$ ____________

$5/8 + 8/16 + 3/4 =$ ____________

$8.123 + 0.197 + 0.018 =$ ____________

2. SUBTRACT:

788	7002	9987
509	1667	5621
____	____	____

$3/4 - 2/3 =$ ____________

$586.7 - 23.6 =$ ____________

$6/7 - 4/28 - 3/8 - 1/4 =$ ____________

$7.496 - 0.230 - 4.001 =$ ____________

3. MULTIPLY:

$7/4 \times 6 =$ ____________

$0.314 \times 1.4 =$ ____________

$8/5 \times 10/24 \times 9/2 =$ ____________

$567 \times 765 =$ ____________

4. DIVIDE:

$3/4 \div 1/8 =$ ____________

$81.25 \div 5 =$ ____________

$14/6 \div 2/3 =$ ______ $\div\ 28/4 =$ ______

$468.24 \div 0.02 =$ ____________

5. CONVERT FRACTIONS INTO DECIMALS:

3/4 = ________

4/5 = ________

7/8 = ________

4/3 = ________

225/1000 = ________

389/100,000 = ________

50-37/100 = ________

6. CONVERT DECIMALS INTO FRACTIONS:

0.25 = ________

0.111 = ________

0.04 = ________

0.3125 = ________

7. CONVERT INTO PERCENTAGES:

25/100 = ________%

48/96 = ________%

4/5 = ________%

3/8 = ________%

PART B

ARITHMETIC REVIEW

Part B - Arithmetic Review

FRACTIONS

General Definitions

(a) Integer

An *integer* is a whole number such as 1, 2, 3, 4, etc.

(b) Fraction

A *fraction* is a part of the whole such as:

- one half (1/2)
- one third (1/3)
- one quarter (1/4)

It can be one or more of the equal parts of anything, i.e.,

1/2; 1/3; 3/4

A fraction is made up of two parts:

(i) *Numerator:* the number above the line in a fraction indicating how many parts of a unit are taken.

(ii) *Denominator:* the number below the line in a fraction indicating how many parts the whole has been broken into.

SIMILAR FRACTIONS

Fractions which have the same denominator:

1/8; 3/8; 5/16; 7/16

PROPER FRACTION

A fraction whose value is less than one:

2/3; 3/4; 5/6

IMPROPER FRACTION

A fraction whose value is equal to or greater than one:

4/3; 2/2; 8/4

MIXED NUMBER

A whole number and a fraction:

1-1/3; 2-1/2; 5-3/4

CALCULATIONS USING FRACTIONS

(1) Multiplication

To multiply a fraction by a fraction: multiply the numerators for new new numerator and multiply the denominators for the new denominator, e.g.,

2/3 x 3/5 = 6/15

An *integer* may be considered as a fraction with one as the denominator, e.g.,

5 = 5/1; 7 = 7/1

Thus the above multiplication rule can be applied to multiply a fraction by an integer, e.g.,

3/25 x 5 = 3/25 x 5/1 = 15/25
1/16 x 3 = 1/16 x 3/1 = 3/16

(2) Division

To divide a fraction by a fraction invert the divisor and proceed as in multiplication, e.g.,

1/3 ÷ 1/2 = 1/3 x 2/1 = 2/3
1/5 ÷ 2/3 = 1/5 x 3/2 = 3/10

To divide a fraction by an integer convert the integer to a fraction (i.e., 5 = 5/1) and proceed as above, e.g.,

$$1/2 \div 5 = 1/2 \div 5/1 = 1/2 \times 1/5 = 1/10$$
$$3/7 \div 2 = 3/7 \div 2/1 = 3/7 \times 1/2 = 3/14$$

Note: $3/5 \div 2/3$ may be written as $\frac{3/5}{2/3}$

(3) Addition and Subtraction

Only similar fractions can be added or subtracted. The numerators are added or subtracted and placed over the common denominator, e.g.,

$$2/5 + 1/5 = 3/5 \qquad 3/7 + 1/7 = 4/7$$
$$5/9 - 4/9 = 1/9 \qquad 7/13 - 3/13 = 4/13$$

If the fractions are dissimilar (i.e., the denominators are not the same), they must be converted to a common denominator before they can be added or subtracted.

Use must be made of the rule that if the numerator and denominator of a fraction are both multiplied by the same number the value of the fraction is not changed, e.g.,

2/3 = 4/6 (numerator and denominator multiplied by two)

1/2 = 4/8 (numerator and denominator multiplied by four)

EXAMPLES

(1) Adding dissimilar fractions:

1/3 = 4/12	2/7 = 6/21	1/3 = 6/18
1/4 = 3/12	1/3 = 7/21	2/6 = 6/18
		2/9 = 4/18
7/12	13/21	16/18

(2) Subtracting dissimilar fractions:

3/5 = 9/15		5/6 = 10/12	
2/15 = 2/15		1/3 = 4/12	
7/15		6/12	

DECIMALS

(1) General

The decimal system is a method of expressing fractions having denominators of 10, 100, 1000, etc., which simplifies mathematical calculations. The decimal point replaces the denominator in a decimal fraction, the size of the denominator being indicated by the position of the decimal point.

One number to the right of the decimal point indicates a denominator of 10, two numbers to the right of the decimal point indicates a denominator of 100, etc., e.g.,

.5 = 5/10   6.2 = 6-2/10
.05 = 5/100   75.06 = 75-6/100
.005 = 5/1000

If the decimal has no associated whole number the usual practice is to place a zero to the left of the decimal point, e.g.,

.5 = 0.5

(2) Conversion of Common Fractions to Decimals

A common fraction is converted to a decimal fraction by dividing the numerator by the denominator, e.g.,

2/5 = 0.4; 9/16 = 0.5625

(3) Finite and Infinite Decimal Fractions

A common fraction which can be expressed exactly as a decimal produces a *finite decimal*

1/2 = 0.5; 1/4 = 0.25

A common fraction which cannot be expressed exactly as a decimal produces an *infinite decimal*

1/3 = 0.333... etc.; 1/7 = 0.14285... etc.

(4) Rounding Off

In practice, infinite decimal fractions must be rounded off. The Operator must decide how many numbers after the decimal point are to be retained depending on the accuracy required. The other figures are discarded according to the following rules:

If the part discarded is greater than 5, increase the last number retained by one, e.g.,

0.178 = 0.18

If the part discarded is less than 5, do not change the last number retained, e.g.,

0.174 = 0.17

If the part discarded is exactly 5, increase the last number retained by one if it is even and do not change the last number retained if it is odd, e.g.,

0.175 = 0.17; 0.185 = 0.19

(5) Placing the Decimal Point

(a) Multiplication

The number of decimal places in the answer is the sum of the decimal places in the numbers being multiplied together, e.g.,

0.25 x 0.3 = 0.075

2 decimal places + 1 decimal place = 3 decimal places

(b) Division

The number of decimal places in the answer is determined by displacing the decimal point to the right in the number being

divided the same number of places as is required to provide a whole number in the divisor (the number by which another number is divided), e.g.,

```
                              3.6
2.14 )7.704     =     214 )770.4
                           642
                           1284
                           1284
                              0
```

<u>Note</u>: When an Operator is solving a mathematical problem, he should know in what range of magnitude to expect the answer. A common error is misplacing the decimal point in the final solution. When the problem has been solved, ask yourself; does the answer make sense? It may save you from some embarassing moments later when the answer is being quoted to your supervisors. *Always check your answer!*

PERCENTAGE

General

Per cent is a simple method of expressing a fraction which has 100 as its denominator, e.g.,

50/100 = 50%; 3/100 = 3%

The terms *common fraction*, *decimal fraction* and *per cent* are related terms. Every fraction can be expressed in any of these three forms, e.g.,

1/2 - 0.5 = 50/100 = 50%

30% = 30/100 = 0.30 or simply 0.3

TABLE SHOWING CORRELATION BETWEEN
COMMON FRACTION, DECIMAL FRACTION AND PERCENT

Common Fraction	Decimal Fraction	Percent
1/4	0.25	25%
1/5	0.20 (or 0.2)	20%
1/8	0.125	12.5% (or 12-1/2%)
1/3	0.333	33.33% (or 33-1/3%)
2/1000	0.002	0.2%

Answers to Arithmetic Review Test

(1)

$$\begin{array}{r} 195 \\ \underline{796} \\ 991 \end{array} \qquad \begin{array}{r} 205 \\ \underline{643} \\ 848 \end{array} \qquad \begin{array}{r} 9876 \\ \underline{5348} \\ 15224 \end{array}$$

4/7 + 2/3 = 12/21 + 14/21 = 26/21 = 1-5/21 = 1.24

12.4 + 36.5 + 41.1 = 90.0

5/8 + 8/16 + 3/4 = 10/16 + 8/16 + 12/16 = 30/16 = 1-14/16
= 1.88

8.123 + 0.197 + 0.018 = 8.338

(2)

$$\begin{array}{r} 788 \\ \underline{509} \\ 279 \end{array} \qquad \begin{array}{r} 7002 \\ \underline{1667} \\ 5335 \end{array} \qquad \begin{array}{r} 9987 \\ \underline{5621} \\ 4366 \end{array}$$

3/4 - 2/3 = 9/12 - 8/12 = 1/12

586.7 - 23.6 = 563.1

6/7 - 4/28 - 3/8 - 1/4 = 48/56 - 8/56 - 21/56 - 14/56
= 5/56

7.496 - 0.230 - 4.001 = 3.265

(3) 7/4 x 6 = 42/4 = 21/2 = 10-1/2 = 10.5

0.314 x 1.4 = 0.4306

8/5 x 10/24 x 9/2 = 80/120 x 9/2 = 720/240 = 3

567 x 765 = 433,755

(4) 3/4 ÷ 1/8 = 3/4 x 8/1 = 24/4 = 6

81.25 ÷ 5 = 16.25

14/6 ÷ 2/3 = 14/6 x 3/2 = 42/12 = 21/6 = 7/2 = 7/2 - 28/4
= 7/2 x 4/28 = 1/1 x 2/4 = 1/2

468.24 ÷ 0.02 = 23412

(5) 3/4 = <u>0.75</u> 225/1000 = <u>0.225</u>

4/5 = <u>0.80</u> 389/100,000 = <u>0.00389</u>

7/8 = <u>0.875</u> 50-37/100 = <u>50.37</u>

4/3 = <u>1.333</u>

(6) 0.25 = <u>1/4</u> 0.04 = <u>4/100</u>

0.111 = <u>111/1000</u> 0.3125 = <u>3125/10,000</u> or <u>5/16</u>

(7) 25/100 = <u>25%</u> 4/5 = <u>80%</u>

48/96 = <u>50%</u> 3/8 = <u>37.5%</u>

METRIC SYSTEM

The metric system is universally used in scientific and laboratory work. It is a measurement system based on the decimal notation.

The standard unit of *length* is the *meter* (slightly more than one yard).

1 meter = 1000 millimeters = 100 centimeters = 10 decimeters

1 meter = 39.37 inches

The standard unit of *volume* is the *litre* (slightly less than one quart).

The definition of a litre is the volume occupied by one kilogram (1000 grams) of pure water at $4^{\circ}C$ and 760 mm of mercury.

1 litre = 10 decilitres = 100 centilitres = 1000 millilitres

Since there are 1000 millilitres in one litre each millilitre of water weighs one gram.

The term *cubic centimeter* (c.c.) is sometimes used interchangeably with millilitre (ml).

The terms *litre* and *millilitre* are common in lab practice. For a rough approximation it is assumed that 20 drops = 1 millilitre.

A comparison of the English System (foot, pound) and the Metric System is given below:

1 meter	=	1.09 yards	=	3.28 feet	=	39.37 inches
1 kilogram	=	2.2 pounds	=	35.3 ounces		
1 pound	=	453.6 grams				
1 litre	=	0.22 gallon	=	0.88 quart		

PART C

WATER TREATMENT PLANT OPERATION

Part C - Water Treatment Plant Operation

FORMULAE

AREA OF TRIANGLE

(with 90° angle) $A = 1/2$ base x height

(with 3 straight lines) $A = 1/2$ (base x height)

AREA OF RECTANGLE

$A =$ Length x Width

AREA OF CIRCLE

$$A = \pi R^2 \text{ or } \frac{\pi D^2}{4}$$

D = diameter

R = radius or 1/2 D

C = circumference

$\pi = 3.14$

VOLUME OF RECTANGULAR SOLID

$$V = L \times W \times H$$

VOLUME OF CYLINDER

$$\pi D^2 \times H$$

1 cubic foot	=	62.4 pounds
1 cubic foot	=	6.24 gallons
1 gallon	=	10 pounds
1 gallon per minute	=	1440 gallons per day
1 cubic foot per second	=	539,000 gallons per day
1 cubic foot per second	=	375 gallons per minute
1 grain per gallon	=	14.3 parts per million
1 Imperial gallon	=	1.2 U.S. gallons
1 U.S. gallon	=	0.833 Imperial gallon
1 pound per square inch	=	2.31 feet of head
Imp. gallons x 1.2	=	U.S. gallons
U.S. gallons x 0.83	=	Imp. gallons

DETENTION TIME: VOLUME OF TANK   PPM = Mg/l

CHLORINE DOSAGE = DEMAND + RESIDUAL

FLOW = VELOCITY x AREA OF PIPE

TEMPERATURE

Convert ^{o}C to ^{o}F: multiply $^{o}C \times 9/5 + 32$
Convert ^{o}F to ^{o}C: $(^{o}F - 32) \times 5/9$

We will test your ability to answer questions like any or all of the following:

Remember, on course tests you are marked not only for providing a correct answer but also for putting down all rough work wherever possible. If you can solve the following you will have no problem doing Mathematics section of course tests.

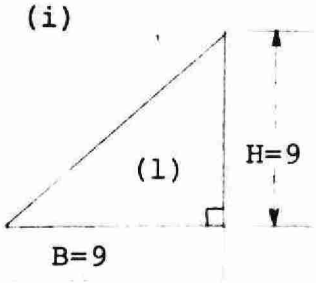
Refer to arithmetic texts available at the public library or

"Mathematics for Water and Wastewater Treatment Plant Operators" (J. Kirkpatrick)
Anne Arbor Science (Publishers)
P.O. Box 1425
Anne Arbor, Michigan 48106

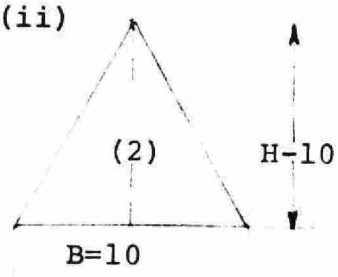
SOLVE THE FOLLOWING:

(1) Find the area of the following:

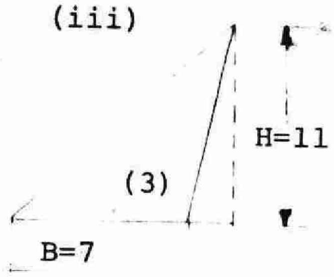
(i)



(ii)



(iii)



Note: In triangle (ii) the two angles at the base and the two sides are equal. All measurements are in feet.

(2) What is the area of a rectangle whose dimensions are 24 inches by 12 inches

(a) in square inches?
(b) in square feet?

(3) What is the volume of a tank whose dimensions are 30 feet by 15 feet by 10 feet deep

(a) in cubic feet?
(b) in gallons?

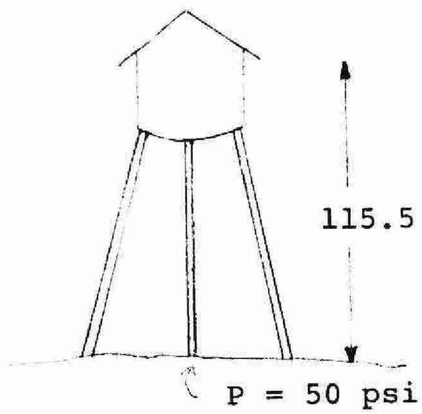
(4) What is the area, in square feet, of a circle which has a diameter of 5 feet?

(5) Find the volume of a cylinder which has a diameter of 6 feet and a height of 11 feet

(a) in cubic feet.
(b) in gallons.

(6) A tank which has a capacity of 60 gallons contains 25 gallons of water, 15 gallons of liquid alum and 20 gallons of lime slurry. What per cent of the total does each of the three substances in the tank represent?

(7) The water pressure at the bottom of an elevated storage tank is 50 pounds per square inch (psi). If the tank has a height of 115.5 feet is there sufficient pressure to fill it?



(8) How many pounds of gas chlorine are required to disinfect 1500 feet of 8-foot-diameter watermain if the required dosage is 50 parts per million?

(9) If the chlorine compound used in question 8 has only 70 per cent available chlorine how many pounds are required?

(10) A rectangle settling tank has a volume of 6,000 cubic feet. How long would it take to fill the tank with a pump rated at 750 gallons per minute?

(11) A 0.00025 per cent solution of copper sulphate is recommended in a water reservoir to control algae. How many pounds of copper sulphate would be required for a 3-million-gallon reservoir?

Note: A 5 per cent alum solution means 5 pounds of alum in 100 pounds of solution. Both the material and the solution are expressed in the same units. Consistent units must be used when per cent (%) is being considered.

(12) A water treatment plant operates at a rate of 3 MGD for 8 hours and feeds chlorine at 2.5 mg/l during this period. During the rest of the 24 hours, the pumping rate is 2 MGD and the chlorine dosage is 2.0 mg/l (ppm). What is the total dosage for the day?

ANSWERS:

1. i) area of triangle with 90° angle = ½ base x height

$$= \tfrac{1}{2}(9) \times 9$$
$$= 4.5 \times 9$$
$$= \underline{\underline{40.5}}$$

ii) area of triangle with 3 straight lines = ½ base x height

or ½(b x h)

$$\text{area} = \tfrac{1}{2}(10 \times 10)$$
$$= \tfrac{1}{2}(100)$$
$$= \underline{\underline{50}}$$

iii) $$\text{area} = \tfrac{1}{2}\ (b \times h)$$
$$= \tfrac{1}{2}\ (7 \times 11)$$
$$= \tfrac{1}{2}\ (77)$$
$$= \underline{\underline{38.5}}$$

2. Area of rectangle = length x width
To find area in square inches; (inches x inches = square inches)

Area = 24 inches x 12 inches
= 288 square inches

To convert to square feet, 1 square foot = 144 square inches
(12 inches x 12 inches)

Therefore, 288 square inches = $\frac{288}{144}$ square feet
= $\underline{\underline{2}}$ square feet

3. Volume of a tank (rectangular) = length x width x height (or depth)

volume = 30 feet x 15 feet x 10 feet
= 4,500 <u>cubic</u> feet

4. Area of circle = πr^2 or $\frac{\pi d^2}{4}$

(π is 3.14 for our purposes)
(r is the radius of a circle)
(d is the diameter of a circle = 2r or 2 x the radius)

Given - diameter as 5 feet $= \frac{3.14 \times (\text{diameter} \times \text{diameter})}{4}$

$$= \frac{3.14 \times (25)}{4}$$
$$= \frac{7850}{4}$$
$$= \underline{19.6 \text{ square feet}}$$

5. Volume of cylinder = Area of circle X height (or length of cylinder)

$$= \left(\frac{\pi d^2}{4}\right)h \quad \text{or} \quad (\pi r^2)h$$

$$\text{volume} = \left(\frac{\pi(6^2)}{4}\right)h$$

$$= \frac{3.14(\cancel{36}^{\,9})}{\cancel{4}\ 1}$$

$$= \underline{\underline{28.26}} \text{ cubic feet}$$

28.26 cubic feet in gallons?
How many gallons in 1 cubic foot? $\underline{\underline{6.24}}$
Therefore no.of gallons = 28.26 x 6.24
= $\underline{\underline{176.34}}$

6. Tank <u>capacity</u> 60 gallons
Tank contains 25 gallons (water)
Tank contains 15 gallons liquid alum
Tank contains 20 gallons lime slurry

What percent does each of the contents represent of the capacity?

$$\frac{25 \text{ gallons}}{60 \text{ gallons}} = \frac{25}{\cancel{60}_{3}} \times \frac{\cancel{100}^{5}}{1} = 41\ 2/3 \text{ or } \underline{41.66\%}$$

$$\frac{15 \text{ gallons}}{60 \text{ gallons}} = \tfrac{1}{4} \text{ or } \underline{25\%}$$

$$\frac{20 \text{ gallons}}{60 \text{ gallons}} = 1/3 \text{ or } \underline{33.33\%}$$

7. How high will 1 lb. of pressure per square inch push the water?

1 lb/sq. inch = 2.31 feet of head

Therefore, 50 lb/sq. inch = 50 x 2.31 feet
= $\underline{\underline{115.5 \text{ feet}}}$

Which means the pressure is adequate to push the water to the desired level. Had the value been less, the pressure would be inadequate, more, more than adequate.

8. Watermain length = 1,500 feet
diameter = 8 inches or $\frac{8}{12} = \frac{2}{3}$ feet or .67

$$\text{volume} = \frac{\pi d^2}{4} \times h \text{ (or length)}$$

$$= \frac{3.14(.67^2)}{4} \times 1{,}500$$

$$= \frac{3.14(.4489)}{\cancel{4}\ 1} \times \overset{375}{\cancel{1{,}500}}$$

$$= 1.409 \times 375$$

$$= \underline{\underline{528.58}} \text{ cubic feet}$$

How many gallons in 1 cubic foot? $\underline{\underline{6.24}}$

528.58 cu. feet = 528.58 x 6.24 gallons
= 3298.34 gallons

How many pounds in 3298.34 gallons?

1 gallon = 10 lbs.

Therefore, 3298.34 gallons = 32,983.4 lbs.
dosage is 50 ppm
lbs. chlorine required (dosage) $= \frac{5\cancel{0} \times 32{,}983.4}{1{,}000{,}00\cancel{0}}$

$= \underline{\underline{1.649}}$ lbs.

9. 70% available chlorine
therefore, 30% more chlorine is needed to satisfy demand.
30% of 1.649 lbs. is $1.649 \times \frac{3\cancel{0}}{10\cancel{0}} = .4947$ lbs.
adding .4947 to 1.649 lbs. = $\underline{\underline{2.14}}$ lbs. is needed.

10. Volume = 6,000 cubic feet
How many gallons in 1 cubic foot? 6.24 gallons in 1 cubic foot.
Therefore, 6,000 cubic feet = 6,000 x 6.24 gallons = **37,440** gal.
Rate of filling = 750 gallons/ minute
Time required to fill $= \frac{37{,}440}{750} \frac{\text{gal.}}{\text{min.}}$

= 49.92 minutes or $\underline{\underline{\text{50 minutes}}}$

11. .00025% = .0000025 (as a decimal)
Therefore, Amount of copper sulphate = .0000025 x 3,000,000 (gal.) x 10 (lbs.) = $\underline{\underline{75}}$ lbs.

(MGD = 24 hours)

12. i) 2 MGD for 8 hours. chlorine @ 2.5 mg/l

ii) 2 MGD for 16 hours. chlorine @ 2.0 mg/l

How many million gallons treated in (i)?

$\frac{8}{24} = \frac{1}{3}$ therefore, $\frac{1}{3}$ of 3 MG = <u>1 MG</u>.

How many million gallons treated in (ii)?

$\frac{16}{24} = \frac{2}{3}$ therefore, $\frac{2}{3}$ of 2 MG = $\underline{\underline{1.3\dot{3}\text{ MG}}}$.

How much chlorine was used in (i)?

@ 2.5 mg/l or ppm $\frac{2.5}{1,000,000} \times 1,000,000 = \underline{\underline{2.5 \text{ lbs}}}$.

How much chlorine was used in (ii)?

@ 2.0 mg/l or ppm $\frac{2}{1,000,000} \times 1,333,333 = \underline{\underline{2.67 \text{ lbs}}}$.

Total pounds per day = 2.5 + 2.67 = $\underline{\underline{5.17 \text{ lbs}}}$.

FORMULAE SEWAGE TREATMENT PLANT OPERATION

AREA OF TRIANGLE

(with 90° angle) $A = \frac{1}{2}$ base x height

(with 3 straight lines) $A = \frac{1}{2}$(base x height)

VOLUME OF RECTANGULAR SOLID

$V = L \times W \times H$

VOLUME OF CYLINDER

$\frac{\pi D^2}{4} \times H$

AREA OF RECTANGLE

A = length x width

AREA OF CIRCLE

$A = \pi R^2$ or $\frac{\pi D^2}{4}$

D = diameter
R = radius or ½ diameter
C = circumference
$\pi = 3.14$

1 cubic foot	=	62.4 pounds
1 cubic foot	=	6.24 gallons
1 gallon	=	10 pounds
1 gallon per minute	=	1,440 gallons per day
1 cubic foot per second	=	539,000 gallons per day
1 cubic foot per second	=	375 gallons per minute
1 grain per gallon	=	14.3 parts per million
1 Imperial gallon	=	1.2 US gallons
1 US gallon	=	0.833 Imperial gallons
1 pound per square inch	=	2.31 feet of head

DETENTION TIME = $\frac{\text{Volume of Tank}}{\text{Flow Rate}}$

PPM = MG/L

CHLORINE DOSAGE =

Demand (ppm) + Residual (ppm)

FLOW

= Velocity x Area of Pipe

SURFACE SETTLING RATE

$= \frac{\text{Flow (gal/day)}}{\text{Surface area (sq. ft.)}}$

PUMP CAPACITY

= Volume/Time

S.V.I. = SLUDGE VOLUME INDEX

$= \frac{\text{\% settleable solids (of 30-min settling test)}}{\text{ppm suspended solids (in the aeration tank)}} \times 10{,}000$

F/M

= lb. BOD/day/lb MLVSS in Aeration Tank

$$\text{TOTAL SOLIDS} = \frac{\text{wt. of dish + dried sample - wt. of empty dish} \times 100\%}{\text{wt. of dish + wet sample - wt. of empty dish}}$$

= % total solids

MLSS or Mixed Liquor Suspended Solids

$$\text{MLSS} = \frac{\text{(dried weight + solids - dried weight)} \times 1{,}000 \times 1{,}000}{\text{volume of sample used for analysis (ml)}}$$

$$\text{MLVSS} = \frac{\text{(dried weight - ashed weight)} \times 1{,}000 \times 1{,}000}{\text{volume of sample used for analysis (ml)}}$$

BOD (MG/L)

$$= \frac{\text{[dissolved } O_2 \text{ content (mg/l) of sample dilution (15 min. after preparation] - [dissolved } O_2 \text{ content (mg/l) of sample dilution (after 5 day incubation)]} \times 100}{\text{\% dilution of sample used}}$$

PART D

SEWAGE TREATMENT PLANT OPERATION

We will test your ability to answer questions like any or all of the following:

Remember on course tests. you are marked not only for providing a correct answer but also for putting down all rough work wherever possible. If you can solve the following you will have no problem doing Mathematics section of course tests.

Refer to an arithmetic test available at the public library or Mathematics for Water and Wastewater Treatment Plant Operators, (J. Kirkpatrick) Anne Arbor Science (Publishers)
P. O. Box 1425,
Anne Arbor, Michigan 48106

Part D - Basic Mathematics for Sewage Treatment Plant Operation

SOLVE:

(1) What is the rate of flow in a pipe with radius 3 feet if the velocity is 2 feet per second?

(2) At a flow of 2 MGD, chlorine is fed at 175 lbs./day. What is the chlorine dosage expressed in mg/l?

(3) Raw sewage influent contains 200 mg/l suspended solids. Primary tank effluent contains 100 mg/l suspended solids. What is percent efficiency?

ANSWERS

1. Flow $Q = V \times A$ (Velocity x Area)

$= 2$ ft/sec x A

Area of pipe cross section (A)

$= \pi r^2$

$= 3.14 \times 9$

$= 28.26$ sq. ft.

$= 2 \times 28.26$

$= 52.52$ cfs

2. 1 gal. sewage = 10 lbs

$$\frac{175 \text{ lbs/day}}{(2 \text{ MGD})(10 \text{ lb})} = \frac{175 \text{ (lbs)}}{2,000,000 \times 10 \text{ (lbs)}} \times 1,000,000$$

$= 8.75$ mg/l

3. $$\frac{[\text{solids in influent (ppm)} - \text{solids in effluent (ppm)}]}{\text{solids in influent (ppm)}} \times 100$$

$$= \frac{(200 - 100)}{200} \times 100 = 50\%$$

Basic Mathematics for
Sewage Treatment Plant Operators

SOLVE THE FOLLOWING: (Assume Imperial Gallons)

1. A 50 ml aliquot of mixed liquor is filtered for a suspended solids analysis. The tare weight of the paper is 0.174 gram. After filtering and drying the paper weighed 0.324 gram. What is the MLSS concentration?

2. If a ton of sludge contains 75% water, what is the weight of solids in the mixture? (1 ton = 2,000 lbs.)

3. Given a raw sewage flow of 1 MGD and a BOD in the raw sewage of 150 mg/l, calculate the lb. of BOD per day entering the activated sludge section assuming a 20% reduction in BOD across the primary clarifiers.

4. Given that a plant has a daily flow of 1.0 MGD and an average primary effluent BOD of 150 mg/l, mixed liquor volatile suspended solids (MLVSS) of 1500 mg/l and an aeration tank volume of 200,000 gallons, calculate the F/M ratio.

$$\text{F/M ratio} = \frac{\text{lb. BOD/day to aeration tanks}}{\text{lb. MLVSS in aeration tanks}}$$

5. If the <u>uptake</u> <u>rate</u> is 20 mg O_2/l/hr and the <u>MLVSS</u> is 4,000 mg/l, what is the specific uptake rate?

$$\text{SUR} = \frac{\text{Uptake Rate x 1000}}{\text{MLVSS (in mg/l)}}$$

6. A 100,000-gallon aeration tank contains 4,000 mg/l MLSS. The return sludge concentration is 12,000 mg/l. How many gallons of sludge should be wasted in order to reduce the MLSS to 3,000 mg/l?

7. Calculate the MLSS and SVI using the following information:

(a)	Weight of paper	= 0.4004
(b)	Weight of paper + solids	= 0.5186
	Sample volume	= 50 mls
	1/2 hour SVI	= 21%

8. A 250-ml sample of final effluent is filtered for a suspended solids analysis. The tare weight of the paper is 0.1560 gram. After filtering and drying, the paper weight is 0.1572 gram. Express the suspended solids concentration in mg/l.

9. An aeration tank has a capacity of 500,000 gallons. If the MLSS is 3,000 mg/l, what is the weight of the solids expressed in lbs.?

10. The MLSS concentration in a 200,000-gallon aeration tank is 4,000 mg/l. This activated sludge contains 75% volatile suspended solids. Express the MLVSS in lbs.

ANSWERS

1. 50 ml aliquot

tare weight of paper 0.174 gram

tare weight after filtering and drying 0.324

from SS formula $\frac{0.324 - 0.174}{50}$ 1,000 x 1,000 = 3,000

MLSS concentration is 3,000 mg/l

2. 75% is water which weighs 75% of 2,000 lbs. or 1,500 lbs.; the solids content must weigh 2,000 - 1,500 or 500 lbs.

3. flow 1 MGD

BOD 150 mg/l

20% reduction mg/l = ppm

$$\frac{150}{1,\cancel{000},\cancel{000}} \times 1,\cancel{000},\cancel{000} \times 10 = 1,500 \text{ lbs.}$$

$$\frac{80}{1\cancel{00}} \times 1,5\cancel{00} = 1,200 \text{ lbs.}$$ BOD over primary clarifiers.

4. flow 1 MGD 1 gallon = 10 lbs.

BOD 150 mg/l mg/l = ppm

tank capacity 200,000 gallons

MLVSS 1,500 mg/l

$$\text{lb. BOD/day} = \frac{150}{1,\cancel{000},\cancel{000}} \times 1,\cancel{000},\cancel{000} \times 10 = 1,500 \text{ lbs}$$

$$\text{lb. MLVSS in aeration tank} = \frac{1,500 \times 2\cancel{00},\cancel{000}}{1,\cancel{000},\cancel{000}} = 3,000 \text{ lb. MLVSS}$$

$$F/M = \frac{1,500}{3,000} = 0.5$$

5. Uptake rate 20 mg O_2/l/hr

MLSS 4,000 mg/l

specific uptake rate SUR = $\frac{20}{4,000} \times 1,000 = 5$ mg O_2/hr/day

6. 100,000 gal. tank

4,000 mg/l MLSS

return sludge 12,000 mg/l

$$X = \frac{(Mo - Ml)}{R}$$

Mo = MLSS (mg/l)

Ml = Required MLSS (mg/l)

V = Aeration tank capacity in gals.

R = SS in sludge return

X = Gallons to waste

$$= \frac{(4,000 - 3,000)}{12,000} \times 100,000$$

$$= \frac{100,00}{12} = \underline{8333.33 \text{ gallons}}$$

7. MLSS = (B - A) x 1,000 x 1,000

$$= \frac{(0.5186 - 0.4004)}{50} \times 1,000 \times 1,000$$

$$= \frac{0.1182}{50} \times 1,000 \times 1,000$$

$$= \frac{11820}{5}$$

MLSS = 2364 mg/l $\quad \frac{\text{30-min settling test result} \times 10,000}{\text{MLSS}}$

$$SVI = \frac{21 \times 10,000}{2364}$$

$\underline{SVI} = \underline{89}$

8. Substituting in formula, $\frac{(0.1572 - 0.1560)}{250} \times 1,000 \times 1,000$

$= 4.8$ mg/l

<u>SS is 4.8 mg/l</u>

9. $\frac{3,000}{1,000,000} \times 500,000 \times 10 = \underline{15,000 \text{ lbs}}.$ solids

10. $\frac{4,000}{1,\cancel{000},\cancel{000}} \times 2\cancel{00},\cancel{000} \times 1\cancel{0} = 8,000$ lbs. MLSS

$\text{MLVSS} = 8,000 \times \frac{75}{100} = 6,000$ lbs. MLVSS

REFERENCES

Kirkpatrick, J. - "Mathematics for Water and Wastewater Treatment Plant Operators" Book 1 Ann Arbor Science, 1973

Manitoba Dept. of Mines, Resources and Environmental Management - Water & Waste School First Year Annual